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BIOSTIMULATION CHARACTERISTICS OF WASTES AND RECEIVING WATERS OF THE SNAKE RIVER BASIN

NATIONAL FIELD INVESTIGATIONS CENTER

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

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BIOSTIMULATION CHARACTERISTICS OF WASTES AND RECEIVING WATERS OF THE SNAKE RIVER BASIN

National Field Investigations Center-Denver
Denver, Colorado
and
Region X, Seattle, Washington

September 1974

II

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GLOSSARY

AGP	- Algal Growth Potential
BOD	- Biochemical Oxygen Demand
cm^2	- Square centimeter = 0.1549 square inch
DO	- Dissolved Oxygen
FWPCA	- Federal Water Pollution Control Administration
g/kg	- Dry weight measured in grams per kilogram of sediment
gm cal	- Gram calorie
kg	- Kilogram = 2.205 pounds
km	- Kilometer = 0.62137 mile
km^2	- Square kilometer = 100 hectares = 0.3861 square mile
lu/m^2	- Lumens per square meter = 0.09 foot-candles
m	- Meter = 3.281 feet = 1.094 yards
m^3	- Cubic meter = 0.0008 acre-feet
m^3/sec	- Cubic meters per second = 35.3 cubic feet per second
µm	- Micrometer
mg/l	- Milligrams per liter
mg/m^2	- Milligrams per square meter
mg C/m^2	- Milligrams of Carbon per square meter
N	- Nitrogen
P	- Phosphorus

I. INTRODUCTION

BACKGROUND

Between 1964 and 1968 the Northwest Regional Office of the Federal Water Pollution Control Administration conducted water quality and pollution sources studies in the Snake River Basin. Objectives of the study were to determine the magnitude and sources of pollution to develop water quality management programs for the Basin. Supplementary data were obtained from local, State, and Federal agencies.

The FWPCA office compiled data from previous studies and prepared a report[1/] that outlined the problems associated with fish kills, algal blooms, bacterial contamination, thermal discharges, radioactive wastes, and pesticide contamination. Detailed conclusions were drawn, and specific recommendations were made for needed State and Federal actions. Waters of the study area were found to be impaired for beneficial uses by increased pollution from industrial, municipal, and agricultural sources. Poor management of various impoundments drastically modified natural flow patterns and impaired assimilation of wastes. Maintenance of minimum stream flow was found to be essential to proper water quality management.

Further studies in 1971 and 1972 by the Environmental Protection Agency (EPA), Region X and the National Field Investigations Center - Denver (NFIC-D) have updated water quality and waste source information.[2,3,4/] Specific nutrient point source data are presented in Appendix A. Substantial upgrading of municipal and industrial waste

treatment has been accomplished in recent years and additional treatment facilities are under construction or planned. Higher levels of treatment may be needed for waste sources if applicable effluent guidelines and water quality standards are to be met. Many problems exist because few advances have been made toward the maintenance of essential minimum stream flows.

1973 INVESTIGATION

At the request of the EPA Region X Administrator, MFIC-D and Region X conducted a four phase study concentrating on nutrient caused algal growth problems in the Snake River Basin. The study area included the Snake River and principal tributaries between Heise, Idaho (River Mile [RM] 857.8) and Brownlee Dam (RM 284.9). The laboratory phase included nutrient analyses, algal growth potential studies, and nutrient removal tests during the period March through May 1973. The monitoring program which began in May 1973 is ongoing and features twice monthly sampling of chlorophyll *a* concentrations, nutrient concentrations, DO, total and fecal coliform bacteria, pH, temperature, and conductivity. An intensive field study was conducted in August 1973 which included nutrient sampling, *in situ* algal assays, primary production measurements, sediment analyses, algal population identification, aerial photography, and field measurements.

Study objectives were:

1. Demonstrate the biostimulatory characteristics of major types of wastewaters being discharged into the Snake River Basin.

2. Assess algal populations, primary production, and nutrient levels in four impoundments of the Snake River.

3. Provide technical information to determine the necessity for nutrient removal from municipal or industrial waste sources in the Basin.

4. Furnish information for the development of municipal and industrial wastewater discharge permits.

DESCRIPTION OF THE AREA

The Snake River originates in the northwest corner of Wyoming, flows through southern Idaho, travels northward b coming the state boundary between Idaho and Oregon, and finally joins the Columbia River in the State of Washington. The river is more than 1,600 km (1,000 mi) long and drains an area of nearly 280,000 km^2 (108,000 mi^2). The study area comprised a 922-km (573-mi) reach from near the Wyoming-Idaho border to the Idaho-Oregon border at Brownlee Dam [Figure 1].

Most of the population inhabits the lowlands of the Snake River and other valleys such as those of the Boise, Portneuf, and Henry's Fork Rivers. Of the Snake River Basin's total area, 42 percent is rangeland; 24 percent is forest; 26 percent is agricultural land; and the remaining 8 percent is divided among other uses.

Agricultural production and processing is the primary economic activity in the basin. There is a phosphate industry in Pocatello and limited manufacturing in the Boise area.

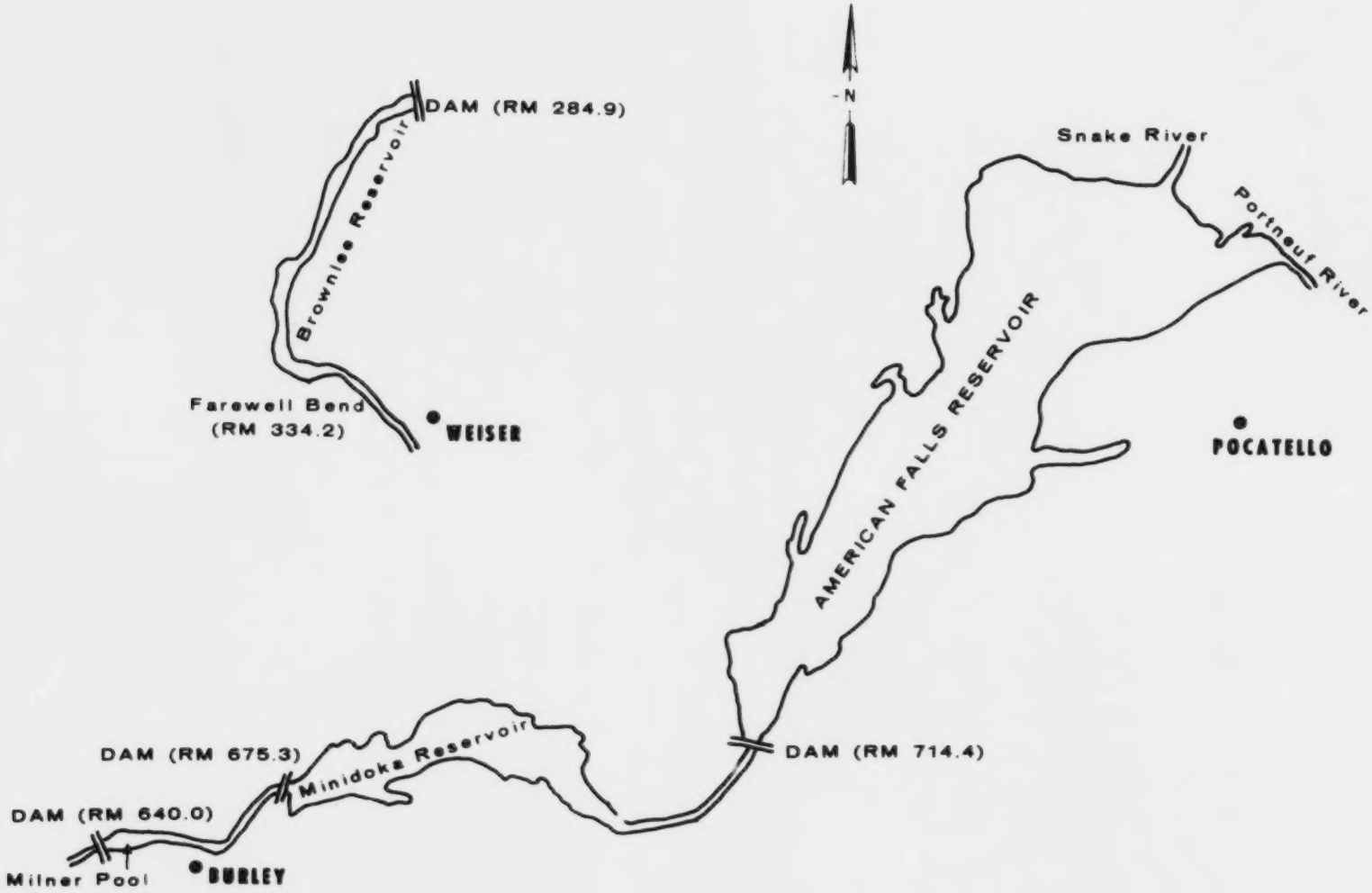

Figure 1. Schematic Map of Snake River Reservoirs
(Not to Scale)

At Heise, Idaho upstream from irrigation diversions, the average annual Snake River flow is about 180 m^3/sec (6,360 cfs). Downstream 400 km (250 mi) at Milner Dam the flow averages 42.6 m^3/sec (1,505 cfs) after irrigation diversions. Downstream from Milner at King Hill substantial inflow, principally from large springs, increases the average flow of the Snake River to about 240 m^3/sec (8,480 cfs). Downstream from King Hill, tributaries increase the flow to about 465 m^3/sec (16,431 cfs) at Brownlee Dam.

Critical low-flow conditions and maximum industrial waste production occur mainly from late summer through winter. Low flows are often "man-made" because storage regulation outweighs natural influence in determining flow patterns. Winter flows diminish as reservoirs are filled for the irrigation diversions. Downstream from significant diversions, the entire flow of the Snake River may cease.

More than 60 Snake River Basin impoundments have individual storage capacities exceeding 6.2 million m^3 (5,000 acre-ft). Algal blooms occur annually in many of the storage areas; they are stimulated by excessive nutrients, nitrogen and phosphorus, that enter the Basin streams or reservoirs from various sources.

APPLICABLE STANDARDS

The Idaho State Water Quality Standards (Appendix B) prohibit introduction of excess nutrients of other than natural origin that cause visible slime or other nuisance aquatic growths. This standard would apply to nutrients causing the algal growths in the reservoirs. Furthermore,

the Standards require minimum dissolved oxygen concentrations of 6 mg/l or 90 percent saturation, whichever is greater, exempting only the bottom 20 percent or 6 m (20 ft) of depth, whichever is less, for natural lakes and reservoirs. Both of these standards establish a water quality limiting situation if algal problems are not solved by implementation of the best practicable control technology currently available (BPCTCA).

II. SUMMARY AND CONCLUSIONS

In each of the reservoirs evaluated (American Falls, Brownlee, Milner and Minidoka), algal bloom conditions (20 mg/l dry weight of algae) were reached with concenrations of 0.1 mg/l total P and 1.0 mg/l inorganic N. Maximum algal growth (71 mg/l dry weight of algae) was stimulated by 1.0 mg/l total P and 10.0 mg/l inorganic N; nutrient additions in excess of these concentrations did not stimulate additional algal growth, and lesser nutrient concentrations stimulated less growth.

During the summer, in situ bottle tests showed nitrogen was the growth limiting nutrient in all of the reservoirs except American Falls. The water of American Falls Reservoir contained sufficient nutrients to sustain algal blooms without nutrient additions. The dominant bloom organism was Aphanizomenon, a blue-green alga capable of fixing atmospheric nitrogen as a growth limiting nutrient. Phosphorus was the growth limiting nutrient in the spring and is more important than nitrogen as long as blue-green algal blooms occur. To eliminate the possibility of algal blooms in the reservoirs, total phosphorus concentrations would have to be reduced to less than 0.1 mg/l. Federal Water Quality Criteria[9] suggest 0.05 mg/l total phosphorus to be the maximum "safe" level for reservoirs. Lowering concentrations of inorganic nitrogen would have long-term benefits also.

Primary productivity was measured on an areal basis, considering the entire water column within the euphotic zone. Because of turbidity,

the euphotic zone of American Falls was restricted to 0.9 m (3.0 ft) or less, while in Brownlee this zone extended from 1.2 to 6.1 m, averaging 3.7 m (4.0 to 20.0 ft, averaging 12.0 ft). If turbidity were decreased in American Falls Reservoir without concurrent nutrient reductions, the algal biomass could increase and there could be a concomitant increase in oxygen demand from algal respiration and decomposition. Therefore, even though Brownlee Reservoir was more productive, American Falls Reservoir appears to have a higher potential for algal problems.

The aerial infrared photographs documented that algal blooms covered much of the surface area of American Falls Reservoir during late August 1973. The algal densities were the heaviest in the western two-thirds of the reservoir.

Algal assays demonstrated that effluent additions to receiving waters stimulate algal growth. However, during the critical summer bloom season up to 44 percent of the nutrient load comes from agricultural sources, and algal blooms would not be eliminated even with a 90-percent reduction of nutrients from all major municipal and industrial sources in the Snake River Basin. Nutrient loadings from agricultural sources are not as well defined as municipal and industrial point sources. Evaluation of possible nutrient load reductions from agricultural sources by treatment or alteration of irrigation practices is needed.

Idaho State Water Quality Standards are being violated for DO and nuisance aquatic growths in the four reservoirs studied. Proposed BPCTCA will not solve existing algal problems. Therefore, the situation is water quality limited and treatment beyond BPCTCA may be required to reduce the nutrient level and subsequently eliminate algal problems.

III. RECOMMENDATIONS

To control algal growth and enhance the quality of the Snake River Reservoirs, the following are recommended:

1. An integrated approach should be used to solve the algal problems in Snake River Reservoirs. Applying strict nutrient controls at any one point would not eliminate algal blooms. The overall plan should incorporate total P reductions from municipal, industrial, and agricultural point sources throughout the system: ultimately, stream levels should not exceed 0.05 mg/l total P.

2. Agricultural sources of nutrients must be controlled. Nutrient loads in cattle feedlot runoff should be reduced by disposing of the runoff on land or treating it in waste stabilization lagoons or by compositing or dehydrating cattle wastes.

3. Soil erosion as a result of irrigation as well as natural runoff must be minimized.

4. Irrigation practices must minimize demands on the Snake River; supplemental irrigation water sources such as ground water and municipal and industrial effluent must be used.

IV. METHODS

Nutrient analyses (TKN, organic N, NO_2+NO_3-N, NH_3-N, ortho and total P) were performed on a Technicon Autoanalyzer using procedures described in EPA Chemical Methods.[5] Nutrient analyses were conducted on all receiving water and effluent samples collected during the survey. Effluent samples were composited over a twenty-four hour period while receiving water samples were collected by grab sampling. Nutrient samples were preserved with mercuric chloride (40 mg/l). All samples for nutrient analyses were labeled, placed in an ice chest, chilled, and transported to NFIC-D or Region X-Seattle for analysis.

Algal growth potential (AGP) tests were performed as outlined in "Algal Assay Procedure-Bottle Test," August 1971.[6] Samples were autoclaved to kill indigenous algae. An inoculum of algae, Selenastrum capricornutum (standard test organisms), was added to each mixture of effluent and receiving water. Standard test conditions (100 ml in 250-ml Erlenmeyer Flasks, 4,306 lu/m^2 (400 ft-candles) of constant light at mid-flask, 24°C waterbath, 88 oscillations per minute shaking, 7-day incubation) remained constant for all tests. Chlorophyll a concentrations were measured initially and daily thereafter by in vivo fluorescence. In situ tests were conducted with the following variations. Receiving water was filtered to remove indigenous algae where facilities for autoclaving were not available. One-liter sample mixtures in cubitainers were incubated in each reservoir for six days under ambient light and temperature conditions. Nutrient additions to receiving waters were tested as described above. Combined serial decimal concentrations of N and P ranging from 0.01 to 10 mg/l were

made using a four-by-four matrix of N (0, 0.1, 1.0, 10.0 mg/1) versus P (0, 0.01, 0.1, 1.0 mg/1) providing 15 different combinations of nutrient additions plus a control.

Removal of N and P was attempted on each effluent. Phosphorus was precipitated by adding hydrated lime (400 mg/1 $Ca[OH]_2$). Next the effluent was heated, stirred, and aerated for two hours to remove nitrogen. After settling, the supernatant was drawn off.

Algae were collected from surface grab filtered samples and artificial substrates (microscope slide, 14-day incubation) and preserved by freezing. In the laboratory, the frozen samples were extracted with 90 percent acetone, and chlorophyll a content, corrected for pheophytin, was determined using a spectrophotometer.

Primary production was measured as outlined in the 13th edition of Standard Methods for Examination of Water and Wastewaters (1971).[7] The depth of the euphotic zone (1 percent light) was determined with a submarine photometer. Light energy received during incubation periods and daily photoperiods were determined with a pyrheliograph. Samples were collected with a Van Dorn sampler. Five 300-ml bottles were filled with water collected from each depth of the subdivided euphotic zone. Three of these bottles were unaltered and considered light bottles. One of the light bottles was fixed immediately and used to measure initial DO. All light penetration was eliminated from the remaining two bottles. The two light and two dark bottles were suspended in the water at the depth from which the sample was obtained, and after incubation the bottles were fixed immediately and iced in a dark container until titration. This holding

period did not exceed 2-1/2 hours. Samples were analyzed according to the azide modification of the Winkler Method.[8/]

To assess algal populations, surface grab water samples were collected and preserved with 5-percent formalin. A Sedgwick-Rafter chamber was used for algal counts.

Field measurements included temperature, pH, conductivity, alkalinity, DO, total and fecal coliform bacteria and flow.

An aerial framing camera mounted in a high performance reconnaissance aircraft was used to record infrared imagery of American Falls Reservoir. The camera was equipped with a Wratten 25 (red) gelatin optical filter and was loaded with Kodak's 2443 Aerochrome Infrared Film.

V. RESULTS AND DISCUSSION

LABORATORY INVESTIGATION (MARCH-MAY 1973)

Nutrient levels in the receiving waters varied extensively [Tables 1,2]. Nutrient concentrations were least in the Snake River at Heise and Henry's Fork upstream of St. Anthony, and they were greatest in tributaries such as the Portneuf River, Rock Creek, the Malheur and Weiser Rivers. In general, nutrient levels increased moving downstream. For example, there was a substantial increase in the nutrient content of the Upper Snake River from Heise, Idaho to the dam at American Falls Reservoir. Industries, municipalities, and polluted tributaries in this reach were major nutrient sources. The nutrient-rich waters from these sources caused total P to triple from 0.02 to 0.06 mg/l and inorganic N to almost double from 0.18 to 0.30 mg/l between Heise and American Falls.

Laboratory assays demonstrated the potential of receiving waters to stimulate algal growth. None of the stream water tested demonstrated an algal bloom.* To experimentally simulate and test unpolluted reservoir water for algal growth potential, reservoir water was prepared artifically by proportionally mixing unpolluted waters from appropriate tributaries [Table 3]. Simulated reservoir water without waste additions did not contain sufficient nutrients to stimulate algal blooms, but Brownlee Reservoir demonstrated a greater potential for algal growth than American Falls Reservoir.

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* A concentrated growth or aggregation of algae sufficiently dense as to be readily visible is a bloom.

TABLE 1

RECEIVING WATER SAMPLING STATIONS
SNAKE RIVER BASIN STUDY

Streams	Description	River Mile
Henry's Fork River	Route 20 Bridge East of St. Anthony, Idaho.	837.4/34.9
North Fork, Teton River	Route 20 Bridge North of Sugar City, Idaho.	837.4/20.4/11.8
Blackfoot River	At Eastern Boundary of Indian Reservation, beginning of paved road.	751.2/47.0
Portneuf River	At Roadside Turnout upstream of Inkom, Idaho.	736.0/30.0
Rock Creek	At First Paved Public Road East of Amalgamated Sugar then South to end of Road and downhill to House.	606.8/13.0
Boise River	Barber Road.	391.3/58.2
Malheur River	First Bridge West of Vale, Oregon.	368.5/19.5
Weiser River	Route 30N Bridge at Weiser, Idaho.	351.8/1.0
Snake River	At Bridge, Heise, Idaho.	857.8
Reservoirs		
Lake Minidoka	At Power Station near Dam.	675.3
Milner Pool	Right Bank (looking upstream) at Dam.	640.01
American Falls	At Boat Ramp, left bank, near Dam.	714.4
Brownlee	At Ranger Station, Farewell Bend, Oregon.	334.2

TABLE 2

NUTRIENT ANALYSIS OF RECEIVING WATERS
MARCH 1973

Stream	Inorganic N (mg/l)		Total P (mg/l)	
	Initial	Autoclaved	Initial	Autoclaved
Snake River	0.18	0.15	0.02	0.01
Henry's Fork, Snake River	0.16	0.12	0.03	0.01
N. F., Teton River	0.39	0.39	0.03	<0.01
Blackfoot River	0.69	0.63	0.14	0.19
Portneuf River	1.04	0.67	0.12	0.15
Am. Falls Resv.	0.30		0.06	
Simulated Am. Falls Resv.		0.38		<0.01
Minidoka Reservoir	0.62		0.10	
Milner Pool	0.68		0.12	
Rock Creek	1.08	0.84	0.09	0.08
Clear Lake Discharge	0.91	0.97	0.06	<0.01
Boise River	0.21	0.24	0.04	0.02
Malheur River	0.17	0.17	0.16	0.15
Weiser River	0.59	0.67	0.28	0.30
Brownlee Resv.	0.77		0.09	
Simulated Brownlee Resv.		0.48		0.03

TABLE 3

SIMULATED RESERVOIR WATER
SNAKE RIVER BASIN STUDY
MARCH 1973

AMERICAN FALLS RESERVOIR (SIMULATED TEST WATER)

Source	% Contribution
Snake River	35
Henry's Fork, Snake River	25
N. Fork, Teton River	20
Blackfoot River	10
Portneuf River	10
	100

BROWNLEE RESERVOIR (SIMULATED TEST WATER)

Source	% Contribution
Simulated American Falls Reservoir	40
Rock Creek	10
Clear Lake Discharge	15
Boise River	15
Malheur River	10
Weiser River	10
	100

Nutrient additions were made to determine if N or P was in short enough supply so as to prevent or restrict algal growth. These additions showed that nitrogen was the limiting nutrient in three tributaries in the Snake River Basin, the Weiser, Malheur, and Boise Rivers. The studies showed that in all other receiving waters tested, including simulated American Falls and Brownlee Reservoirs, phosphorus was the growth limiting factor [Table 4]; therefore, any reduction in phosphorus would reduce algal growth in the reservoirs.

Representative plants of six different waste sources [Table 5] known to co tribute heavy nutrient loads (Appendix A) were selected for algal assays. Assay results indicated that river waters mixed with 10 percent or more of meat packing wastes, treated sewage, or phosphate reduction wastes stimulated algal blooms. On the basis of total load, sewage and potato processing wastes are the greatest nutrient contributors, followed by phosphate reduction wastes, with fish hatchery and sugar beet wastes contributing the least load* [Figure 2]. Irrigation sources are significant and may contribute up to 44 percent of the nutrient load.[2/]

Laboratory experiments were successful in stripping at least 84 percent of the nutrients from industrial effluents [Table 6]. Algal growth potential tests were performed to demonstrate the effect of nutrient stripping on the growth of algae. Wastewater from the six industries were proportionally mixed with simulated reservoir water and AGP tests were conducted. Results showed that the combination of effluents mixed with American Falls and Brownlee Reservoir water stimulated bloom conditions by producing 19.2 and 27.6 mg/l (dry weight) algae within 7 days

* Unpublished data[2/] for upstream of Idaho Falls to Milner Dam.

TABLE 4

ALGAL GROWTH LIMITING NUTRIENT DATA
SNAKE RIVER BASIN STUDY

Date	Station	Limiting Nutrient	Bloom Concentrations (mg/l)	
			N	P
March 1973	American Falls (simulated)	P	1.38	0.11
	Brownlee (simulated)	P	1.48	0.13
August 1973	American Falls	None	0.26	1.2
	Minidoka	N	1.16	0.09
	Milner	N	1.15	0.13
	Brownlee	N	1.03	0.12

TABLE 5
MUNICIPAL AND INDUSTRIAL SAMPLING STATIONS
SNAKE RIVER BASIN STUDY
MARCH AND AUGUST 1973

Type of Waste	Industry	Receiving Water (River Mile)	Treatment at Time of Sampling	Month	Nutrient Concentrations Inorganic N mg/l	Total P mg/l	Nutrient Reductions Achievable by BPT[a]
Sugar-beet processing	Amalgamated Sugar[b] Paul, Idaho	Canal to Snake River (646.9/8.7)	In plant controls Sewage lagoon Closed flume system	March	3.8	1.4	Unknown (typical characteristic values of beet sugar wastes prior to treatment: Total Phosphorus mg/l = 0.06.)
Potato processing	J. R. Simplot, Caldwell, Idaho	Boise River (391.3/17.6)	Primary treatment, holding ponds	March	40	7.9	Unknown.
Meat packing	Golden Valley Packers Roberts, Idaho	Snake River (812.6)	Lagoon	March August	49 61	8.3 6.7	N and P 30-60 percent
Phosphate reduction	J. R. Simplot (001) Pocatello, Idaho	Portneuf River (736.0/13.6)	Settling pond	March August	22.5 40.5	5.9 51	N and P 100 percent
Fish hatchery	Thousand Springs Trout Farm, Buhl, Idaho	Clear Lake (588.8/1.0)	None	March August	1.3 1.5	0.19 0.04	N 0-50 percent P 20-80 percent
Treated sewage	Pocatello Sewage Treatment Plant, Pocatello, Idaho	Portneuf River (736.0/11.6)	Primary treatment	March August	16 23	7.6 13	N and P 20-40 percent
Potato processing	Simplot Potato Burley, Idaho	Snake River (653.8)	Screening, settling, grease removal, extended aeration, activated sludge, secondary clarifier	August	4.6	9.4	Unknown (Simplot at Burley capable of 30-day average final effluent concentrations[c] of 8.5 mg/l NH_3 & 1.2 mg/l PO_4.
Irrigation	Waste Stream near Spring Creek at Bronco Road	Canal to Portneuf River(736.0/13.3/0.1)	None	August	0.24	0.05	Not available.
Irrigation	South Parks - Lewisville Canal	Canal to Snake River (815.0/1.2)	None	August	0.12	0.05	Not available.

[a] Information obtained from respective Development Documents for Proposed Effluent Limitations Guidelines and New Source Performance Standards.

[b] Collected in January, 1973.

[c] 1972-73 Campaign.

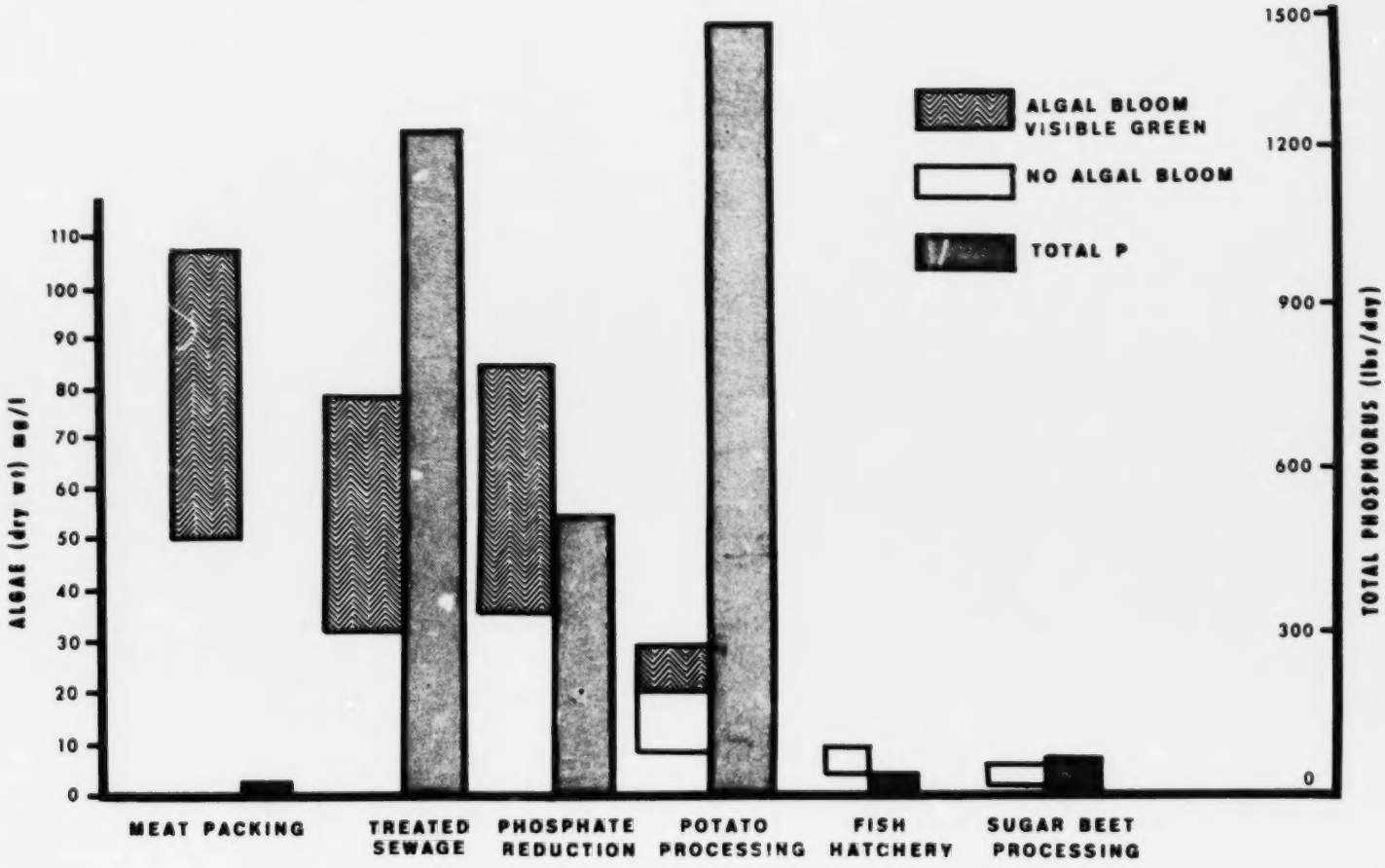

Figure 2. A Comparison of Algal Stimulation by 10% Effluent Additions to Receiving Waters

March 1973

TABLE 6

NUTRIENT REMOVAL TESTS
MARCH AND AUGUST[a] 1973

Type of Waste	Inorganic - N			
	Initial	Autoclaved	Stripped	% Removal
Potato Processing	40.0	16.4	2.2	94
Meat Packing	49.0 (61.0)	36.0	4.18 (2.3)	91 (96)
Treated Sewage	16.4 (23.0)	11.7 (8.0)	2.23 (2.2)	86 (90)
Phosphate Reduction	22.5 (40.5)	14.8 (22.6)	3.38 (0.7)	85 (98)
	Total - P			
Potato Processing	7.9 (9.4)	8.2 (8.1)	0.86 (0.9)	89 (90)
Meat Packing	8.3 (6.7)	8.5	1.26 (1.1)	85 (84)
Treated Sewage	7.6 (13.0)	7.8 (8.5)	0.32 (0.8)	96 (94)
Phosphate Reduction	5.6 (51)	6.0 (37)	0.08 (0.01)	99 (99)
Irrigation	(.05)	(.06)	(.01)	(80)

[a] August values in parentheses.

under laboratory test conditions. When a similar combination of nutrient-stripped effluents were tested in the reservoir waters, the maximum amount of growth was reduced by approximately two-thirds. This reduction would preclude an algal bloom if the only source of nutrients was municipal and industrial. These tests demonstrate the difference between present untreated (for nutrient removal) discharges and levels of treatment that would help solve algal problems.

MONITORING PROGRAM (MAY 1973)

To detect changes during the algal bloom season, 21 stations [Table 7] were monitored beginning mid-May and are continuing. Chlorophyll *a* analyses of stream and reservoir algae, collected by surface grab sampling and from artificial substrates, revealed great fluctuations from May until October. Aerial photography showed that algae were not uniformly distributed. The fluctuations could be caused by the sampling location not always coinciding with a patch of heavy algal concentration. The lowest periphyton chlorophyll *a* concentrations were found on the Snake River at Heise (0.2 to 0.8 mg/m^2) while higher concentrations (up to 10.8 mg/m^2 in Lake Milner) were found on the reservoirs. Nutrient concentration followed a similar pattern, lowest at Heise and higher on the reservoirs. Plankton samples had chlorophyll *a* concentrations as high as 106.5 mg/m^3 for the Snake River at Marsing and 77.5 mg/m^3 for Brownlee Reservoir at the Dam.

Nutrient levels [Table 8] in water released from the reservoirs decreased during the summer, corresponding to increased algal concentrations. For example, downstream from American Falls Reservoir in mid-May nutrient

TABLE 7

RECEIVING WATER SAMPLING STATIONS
May 1973-January 1974
SNAKE RIVER BASIN STUDY

Station Description	River Mile
Henry's Fork downstream from Ashton Reservoir	837.4/44.0
Henry's Fork upstream of St. Anthony	837.4/34.9
Falls River near Mouth	837.4/40.0/0.6
Teton River upstream of Teton	837.4/20.4/22.5
Henrys Fork south of Parker	837.4/29.0
Henrys Fork at Rexburg	837.4/11.0
Snake River near Heise	857.8
Snake River at Roberts	819.9
Blackfoot River near Mouth	751.2/0.1
Snake River at Tilden Bridge	751.0
Portneuf River at Siphon Road Bridge	736.0/11.7
Spring Creek at Rowlands Dairy	736.0/13.3
Spring Creek at Bronco Road	735.5/11.25
Snake River downstream from American Falls Reservoir	714.0
Snake River downstream from Minidoka Dam	671.2
Main Drain near Mouth (Receives sugar refinery wastes, October - March.)	646.9/0.1
Snake River at Milner Dam	640.0
Snake River at Marsing	424.0
Boise River at Parma	391.3/5.0
Snake River at Weiser	350.3
Snake River at Brownlee Dam	284.9

TABLE 8

TOTAL PHOSPHORUS CONCENTRATIONS (MG/L) OF RECEIVING WATERS
MAY 1973-JANUARY 1974

River Mile	Station Description	May	June			July			August		September		October		November		December		January	
		Mid*	Early*	Mid	Late	Early	Mid	Late	Early	Late**	Mid	Late	Mid	Late	Early	Mid	Early	Mid	Early	Late
837.4/44.0	Henry's Fork Downstream from Ashton Resv	0.050	0.030	0.030	--	0.020	0.030	--	0.030	0.040	0.020	--	0.020	0.030	--	0.020	0.020	0.010	--	0.020
837.4/34.9	Henry's Fork Upstream of St. Anthony	0.060	0.030	0.030	--	0.020	0.020	--	0.030	0.047	0.020	0.040	0.020	0.020	--	0.020	0.020	0.020	0.030	0.020
837.4/29.0	Henry's Fork South of Parker	0.080	0.040	0.030	--	0.040	0.040	--	0.050	0.050	0.030	0.040	0.030	0.020	--	0.030	0.020	0.020	0.030	--
837.4/11.0	Henry's Fork at Rexburg	0.110	0.060	0.050	--	0.060	0.050	--	0.070	0.073	0.030	0.050	0.030	0.040	--	0.040	0.030	0.040	0.040	0.040
837.4/11.1/23.5	Teton River North of Newdale	0.210	0.050	0.040	--	0.030	0.010	--	0.020	0.290	0.020	--	0.010	0.010	--	0.040	0.020	0.020	0.040	0.040
857.8	Snake at Heise	0.170	0.030	0.030	--	0.020	0.020	--	0.030	0.026	0.020	--	0.010	0.010	--	0.010	0.010	0.010	--	0.010
816.2	Snake at Roberts	0.120	0.040	0.050	--	0.030	0.030	--	0.020	0.030	0.020	--	0.030	0.060	--	0.030	0.020	0.040	--	0.030
751.2/0.1	Blackfoot River at Mouth	0.270	0.070	0.150	--	0.090	0.160	--	0.050	--	0.050	--	0.120	--	0.150	0.080	0.060	0.060	0.020	0.240
751.0	Snake at Tilden Bridge	0.120	0.050	0.080	--	0.040	0.050	--	0.040	--	0.050	--	0.040	--	0.040	0.070	0.040	0.050	0.040	0.050
736.0/13.3	Spring Rowlands	--	0.410	0.850	--	0.270	0.340	--	0.200	--	0.370	--	0.540	--	0.560	0.560	0.800	0.610	0.340	0.870
736.0/11.7	Portneuf River at Siphon Road	0.300	0.360	0.570	--	0.700	0.610	--	0.480	--	0.420	1.500	0.500	--	0.570	0.430	0.380	1.370	0.360	0.940
735.5/11.25	Spring Creek Bronco Road	--	0.020	0.020	--	0.020	0.020	--	0.020	--	0.030	--	0.020	--	0.020	0.020	0.020	0.020	0.030	0.020
714.0	Snake River Downstream from American Falls	0.120	0.070	0.080	--	0.070	0.120	0.100	--	--	0.160	0.260	0.120	0.100	--	0.100	0.100	0.100	--	0.100
671.2	Snake Downstream from Minidoka	0.060	0.040	0.070	--	0.050	0.090	0.090	--	--	0.130	0.150	0.080	0.110	--	0.110	0.090	0.100	--	0.110
646.9/1.8	Main Drain	--	0.130	0.170	--	0.290	0.220	0.500	--	--	0.250	0.150	0.880	0.640	--	0.460	0.810	1.280	--	--
640.0	Milner at Dam	0.090	0.060	0.080	--	0.080	0.100	0.120	--	--	0.150	0.140	0.110	0.140	--	0.140	0.150	--	0.130	0.150
424.0	Snake at Marsing	0.110	0.060	--	0.070	0.060	0.060	0.070	--	--	0.060	0.070	0.070	0.060	--	0.060	0.060	0.040	0.070	0.080
391.3/5.0	Boise at Parma	0.700	0.340	--	0.340	0.550	0.480	0.340	--	--	0.250	0.280	0.360	0.270	--	0.390	0.300	0.320	0.340	0.420
351.8	Snake at Weiser	0.170	0.140	--	0.160	0.140	0.150	0.140	--	--	0.090	0.170	0.100	0.100	--	0.260	0.150	0.120	0.080	0.160
283.0	Snake Downstream from Brownlee	0.060	0.040	--	0.040	0.030	0.030	0.060	--	--	0.090	0.090	0.100	0.070	--	0.130	0.0 J	--	0.090	0.130

*Early includes the first ten days of the month, mid the second ten days, and late the 21st to the end of the month.
**Average of three days' analysis.

concentrations were 1.04 and 0.03 mg/l for inorganic N and total P, respectively. From June through July the levels ranged from 0.09 to 0.18 mg/l for inorganic N and 0.03 to 0.05 mg/l for total P. By mid-September the concentrations had increased to 0.85 and 0.16 mg/l for inorganic N and total P, respectively.

FIELD INVESTIGATIONS (AUGUST 1973)

Nutrients

Background Concentrations--Receiving waters were sampled upstream of major population areas and industries. These sites were chosen to reflect background or natural nutrient concentrations, but water quality in each reach may have been influenced by runoff from irrigation systems and grazing land. Nutrient levels varied greatly [Table 9]. Maximum stream values for total P and inorganic N were 0.31 and 1.31 mg/l, respectively. Minimum stream values were 0.02 mg/l for both total P and inorganic N. In some stream reaches, background nutrient concentrations were high enough to cause algal blooms. Laboratory results have shown that 0.1 mg/l total P and 1.0 mg/l inorganic N were sufficient nutrient concentrations to cause an algal bloom [Table 4]; these nutrient levels stimulated 20 mg/l (dry weight) algae [Figure 3].

Sediments from 25 locations in American Falls Reservoir contained from 0.63 to 1.42 g/kg (dry weight) total P. Under laboratory conditions, available phosphorus from these samples ranged from 0.51 to 1.06 mg/l (dry weight). The available P was 82 $\pm$ 7 percent of the total P values. Nutrients from this source would increase background concentrations.

TABLE 9

NUTRIENT ANALYSIS OF RECEIVING WATERS

AUGUST 1972

Station Description	Inorganic N			Total P		
	Initial	Autoclaved	Filtered	Initial	Autoclaved	Filtered
Snake River	.04, .09			.02, .03		
Henry's Fork, Snake River	.01, .04			.05, .03		
North Fork, Teton River	.04, 1.5			.10, .04		
Blackfoot River	.06, .16			.02, .06		
Portneuf River	.16, .39			.04, .12		
American Falls Reservoir	.05	.26		.18	1.2	
Simulated American Falls Reservoir		.14	.10		.35	.03
Minidoka Reservoir	.16		.08	.09		.05
Milner Pool	.15		.12	.13		.06
Rock Creek	1.31			.08		
Clear Lake Discharge	1.15			.06		
Boise River	.11			.03		
Malheur River	.79			.31		
Weiser River	.48			.29		
Brownlee Reservoir	.03					
Simulated Brownlee Reservoir			.74			.07

Limiting Nutrients--Nutrient levels directly affected the amount of algae present. The nutrient in shortest supply to the algae limited their growth. The limiting nutrient changed with varying stream conditions and waste sources. This was evidenced by the fact that in March 1973 phosphorus was the limiting nutrient for reservoirs of the Snake River, while in August 1973 nitrogen was found to be limiting except in American Falls Reservoir. American Falls Reservoir contained nutrient concentrations high enough to cause algal blooms without nutrient additions. This change corresponded to changing effluent sources and the amount of phosphorus available compared to the amount of nitrogen.

A filamentous blue-green alga, Aphanizomenon, was present in all plankton samples [Table 10]. The presence of Aphanizomenon negated the effect of nitrogen limitation because this alga is capable of fixing atmospheric nitrogen. Reduction of phosphorus concentrations would reduce algal growths. To eliminate the possibility of algal blooms, concentrations of less than 0.1 mg/l total P would have to be achieved. Federal Water Quality Criteria[9/] recommend 0.05 mg/l total P as a desirable guideline for streams that enter reservoirs, and this should be the goal for the Snake River Basin. Reservoir recovery time would depend on many factors, including the amount of nutrients available from sediments.

Nutrient Removal--Nutrient removal tests were conducted on effluents collected in both March and August 1973 [Table 6]. Results indicate nutrient loadings, described in the "Methods" section of this report, would be reduced through this type of treatment.

TABLE 1c

ALGAL POPULATION, AUGUST, 1973

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Genera or Genus-Group	American Falls Reservoir			Minidoka Reservoir	Milner Pool	Brownlee Reservoir				
	Near Little Hole (724.8)	Near Seagull Bay (718.5)	At Dam (714.4)	At Dam (675.3)	At Dam (640.0)	Farewell Bend(334.2)	Near RR Bridge (328.3)	Near Morgan Crk (318.0)	Brownlee Creek Cove (288.1)	Boat Ramp Near Dam(285.1)
Blue-Green										
Anacystis				308	308				528	629
Chroococcus									Q[a]	
Total				308	308				529	629
Filamentous Blue-Green										
Aphanizomenon	1,309	1,105	952	54,560	4,224	391	440	68	13,728	1,054
Schizothrix									Q	
Spirulina						17			44	17
Total	1,309	1,105	952	54,560	4,224	408	440	68	13,773	1,071
Coccoid Green										
Ankistrodesmus						221	88			
Micractinium						136				
Pediastrum						17				
Scenedesmus						136	176			
Total						510	264			
Filamentous Green										
Spirogyra	68					153				
Total	68					153				
Green Flagellates										
Eudorina		34	17		132	68	132		396	
Euglena				88	264					
Total		34	17	88	396	68	132		396	
Dinoflagellates										
Ceratium	17	68	34							
Peridinium						51				
Total	17	68	34			51				
Centric Diatoms										
Cyclotella	188	34				1,598	1,188			
Melosira						Q				
Other Centric Diatoms	51	34		176	88	2,227	1,100	6,443		
Total	239	68		176	88	3,826	2,288	6,443		
Pennate Diatoms										
Fragilaria			34			34	132			
Navicula	170				132	527	484			
Nitzchia	34				44	136	352			
Other Pennate Diatoms	102	68		220		289	440			17
Total	306	68	34	220	176	986	1,408			17
Total (No./ml)	1,938	1,343	1,037	55,352	5,192	6,002	4,532	6,511	14,698	1,717
Total (No. of Kinds)	8	6	4	5	7	16	11	2	6	4
Primary Production ($mgc/m^2/day$)	724	259	670	5,159	3,046	--	3,830	1,742	1,480	--

a/ Q = 1

From the data collected in October 1971, and March and August 1972, applying nutrient removal to all municipal and industrial waste sources without controlling agricultural sources would not eliminate algal blooms. Published information[10,11] indicates that the Upper Snake River received 0.7 million kg (1.5 million lb) total P per year divided about evenly between agriculture and municipal and industrial sources. With an average Snake River flow of 184 m^3/sec (6,501 cfs), 0.12 mg/l total P are contributed by point sources. The Snake River at Heise contains 0.02 mg/l total P, and most of the tributaries contain greater concentrations, even upstream of major municipalities and industries. Reducing municipal and industrial sources by 90 percent results in net reductions of 29 and 64 percent, based on October 1971 and August 1972 studies. Assuming an initial concentration of 0.14 mg/l total P (0.12 mg/l from point sources and 0.02 mg/l from background sources), a 29- to 64-percent reduction would leave 0.10 to 0.05 mg/l total P. Total P concentrations of 0.1 mg/l stimulate algal blooms. Also, as applies to the Portneuf River entering American Falls Reservoir, concentrations of total P are much higher than 0.1 mg/l.

Agricultural sources of nutrients need to be evaluated. The irrigation return water tested contained only 0.05 mg/l total P and grew only 1.57 to 7.35 mg/l (dry weight) algae, about the same as simulated reservoir water (1.44 to 7.62 mg/l). However, the nutrient monitoring data [Table 8] reveal that other irrigation returns contain as much as 0.50 mg/l total P. Irrigation returns are large volume flows, sometimes comprising the entire river. On a load basis, irrigation return water is a signifiant source.

The laboratory and field tests have shown 1.0 mg/l inorganic N and 0.1 mg/l total P will stimulate an algal bloom (20 mg/l dry weight of algae). Reducing nutrient levels in municipal and industrial sources by 90 percent will not always result in reservoir concentrations that would prevent algal blooms. Further reductions may be achieved by controlling agricultural sources.

Comparison of absolute inputs of total phosphorus generally does not provide a satisfactory means of accurate analysis regarding algal problems in American Falls Reservoir. Total loading data offer little hope for the usefulness of nutrient control. There are high relative loadings from non-point sources from which nutrient removal would be difficult. However, the relative concentrations and flows must be examined; that is, high concentration, low volume inputs can be more important than low concentration, high volume non-point sources.[12/] This is true because low concentration, high volume flows displace a large volume of low concentration water and do not greatly change the nutrient concentration. A high concentration, low volume flow displaces only a small volume of water and raises local concentrations to levels that cause increased algal growth. Thus, concentration is more important than load for algal growth. For example, the Snake River entering American Falls has a lower concentration of total phosphorus than the Snake River downstream from American Falls Reservoir. The Portneuf River is a low volume, high concentration flow compared to the Snake River. The net input then is negative for the Snake River and 100 percent for the Portneuf River. The first step in solving algal problems of American

Falls Reservoir would be control of point sources on the Portneuf River. Major point sources on the Snake River should also be controlled.

Algal Growth Potential Tests

To verify laboratory predictions, algal growth potential tests were conducted *in situ*. Receiving water sampling sites were identical to those used in March [Table 1]. Wastes used [Table 5] included potato processing, fish hatchery, phosphate reduction, treated sewage, meat packing and irrigation return. Receiving waters [Table 11] simulating Minidoka, Milner, and Brownlee Reservoirs were filtered, while receiving water simulating American Falls Reservoir was autoclaved. Filtering or autoclaving removed or destroyed indigenous algae. The six wastes were combined with simulated reservoir [Table 11] water in duplicate serial dilutions to test varied nutrient loads. Dilutions were based upon reported river flow and industrial effluent data so that the laboratory conditions were similar to actual river conditions. The same test algae, *Selenastrum capricornutum*, was added to each mixture.

The mixtures were made in one-liter cubitainers and incubated *in situ* in each reservoir. Initial and daily *in vivo* fluorescence readings to measure relative algal growth were made with a Turner fluorometer for six days.

The *in situ* algal assays demonstrated the potential of six different wastes to stimulate algal growth in major Snake River Reservoirs. Results from the laboratory and *in situ* assays were similar. Potato-processing, treated sewage, phosphate reduction, and meat packing wastes all contained sufficient nutrients to stimulate algal blooms. A 10-percent addition of

TABLE 11

SIMULATED RESERVOIR WATER, AUGUST 1973

SNAKE RIVER BASIN STUDY

AMERICAN FALLS RESERVOIR (SIMULATED TEST WATER)	
Source	% Contribution
Snake River	30
Henry's Fork, Snake River	30
North Fork, Teton River	20
Blackfoot River	10
Portneuf River	10
	100

BROWNLEE RESERVOIR (SIMULATED TEST WATER)	
Simulated American Falls Reservoir	10
Rock Creek	10
Clear Lake Discharge	40
Boise River	20
Malheur River	10
Weiser River	10
	100

these wastes, corresponding to adding more than 0.8 mg/l inorganic N and 0.6 mg/l total P, caused algal blooms in simulated reservoir mixtures. With 1-percent additions (0.08 mg/l inorganic N and 0.06 mg/l total P) blooms were not stimulated. Stream concentrations of total P [Table 8] ranged from 0.01 to 1.5 mg/l. Treated sewage and meat packing wastes stimulated the most dense algal growths, on the basis of maximum standing crop [Figure 3], followed by phosphate reduction, potato processing, fish hatchery, and irrigation return wastes. Treated sewage, potato processing and irrigation return contribute the greatest load, on the basis of total loadings of nutrients, followed by phosphate reduction, with meat packing and fish hatchery wastes contributing least [Figure 4].

Maximum yields under ideal laboratory conditions correlated closely with actual yields in natural situations. For each µg/l total P about 0.2 mg dry weight of test algae was produced. Consequently, each µg/l total P that can be removed from the system will reduce the algal load by 0.2 mg dry weight.

The algal growth potential tests have shown that Idaho State Water Quality Standards are being violated, in that the amount of algae is directly related to nutrient concentrations and also that nutrients provided by the waste sources tested do stimulate algal growth. Loading data define nutrient point sources and demonstrate that "excess nutrients of other than natural origin" are present. The nuisance aquatic growths (algal blooms) in the reservoirs are caused by nutrients in excess of "natural origin."

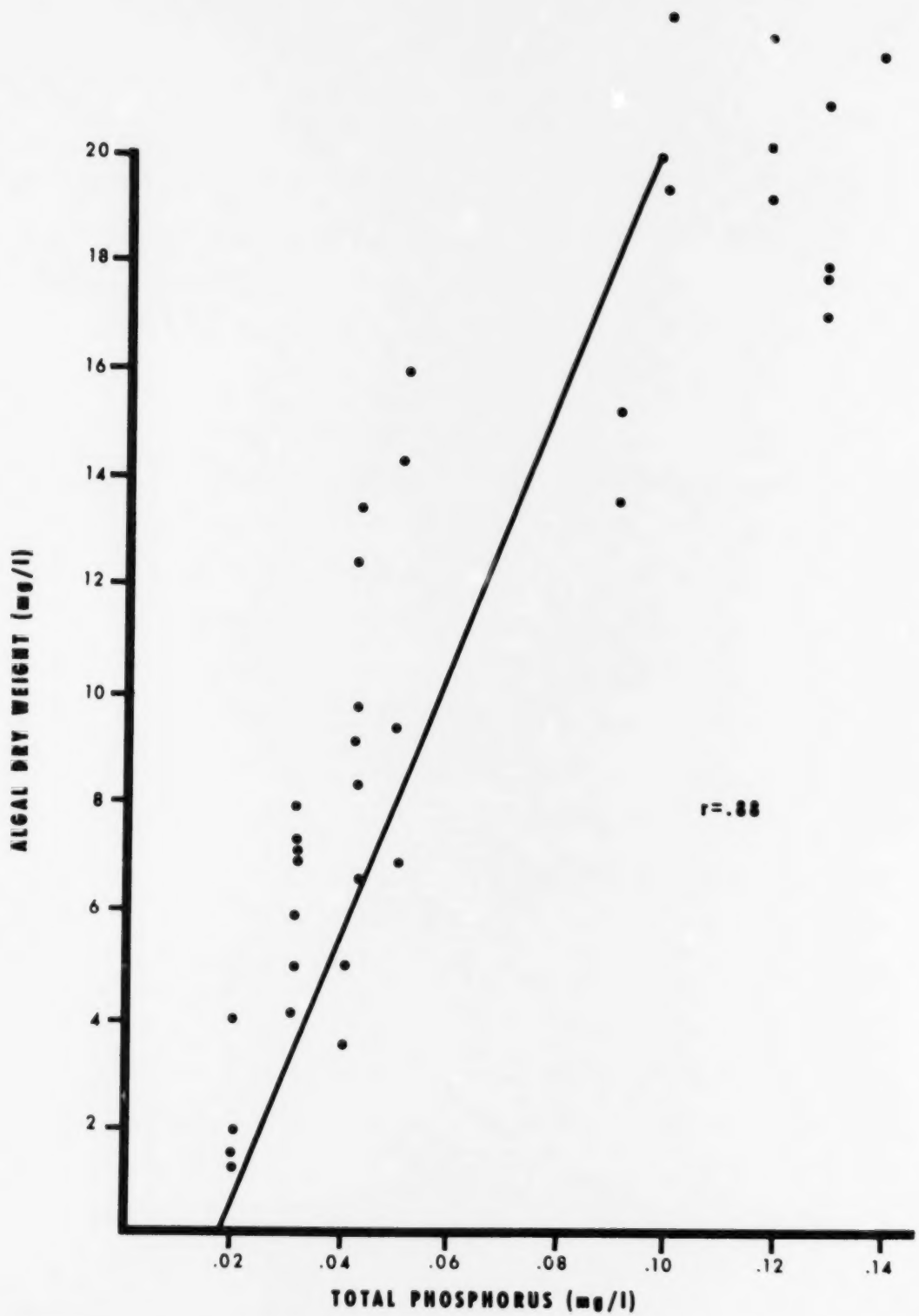

Figure 3. Relationship of Algal Standing Crop and Total Phosphorus

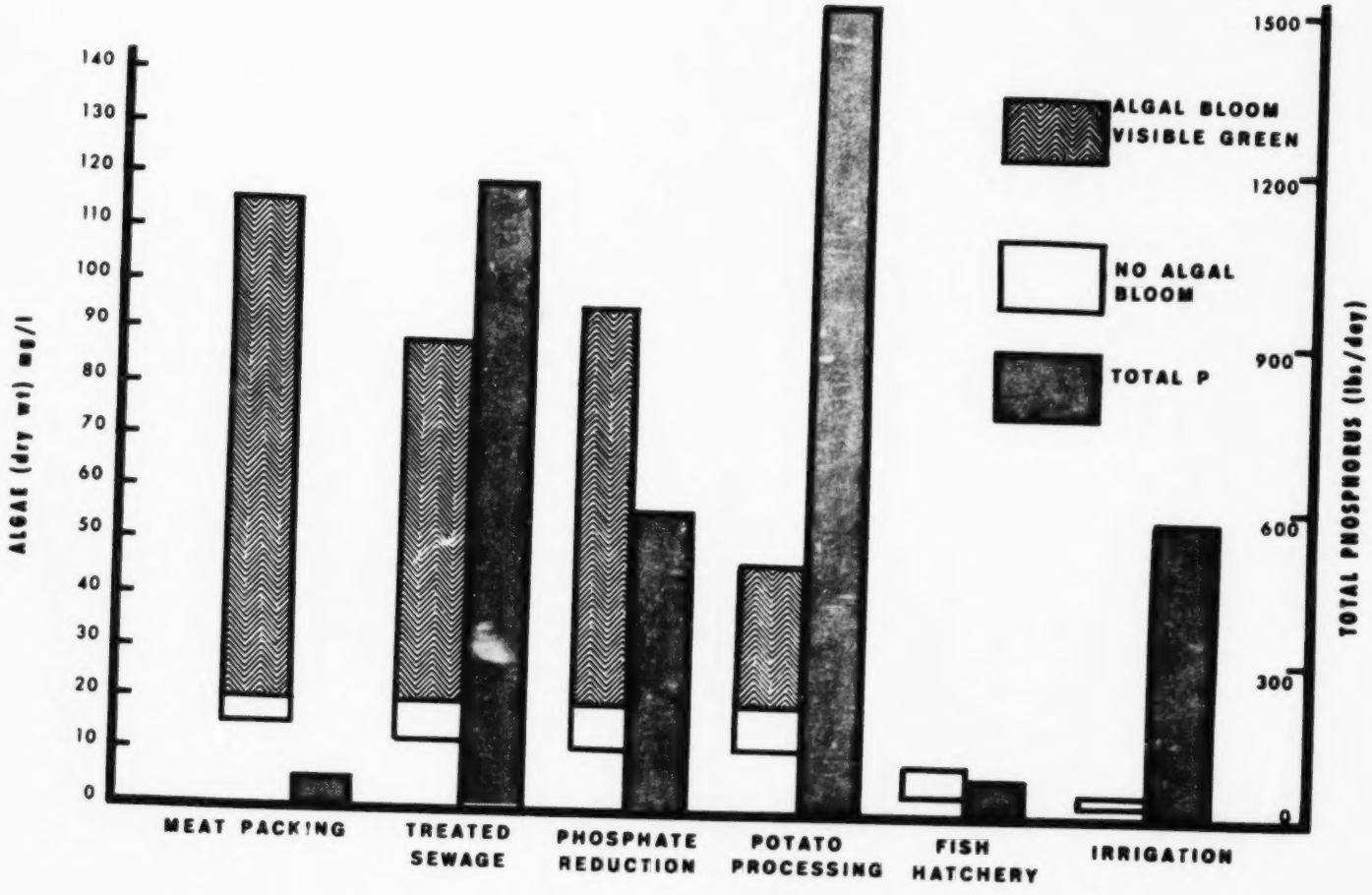

Figure 4. A Comparison of Algal Stimulation by 10% Effluent Addittions to Receiving Waters

August 1973

Primary Production

Estimates of primary production by phytoplankton were made in duplicate at two or three depths at each of eight stations [Table 12]. The oxygen method presented in Standard Methods[7/] was used for all stations. The interval between the depths was determined by subdividing the euphotic zone (the zone between the surface and the depth at which one percent of the incident light remains). The depth of the euphotic zone was determined with a submarine photometer. For all stations, samples were taken at the surface and the bottom of the euphotic zone depth. If the euphotic zone depth exceeded 2 m (6.6 ft), a mid-zone sample was also taken. Light energy received during incubation periods and daily photoperiods was determined with a pyrheliograph. The light energy values were reported in gram calories per cm^2 per day [Table 13].

The results obtained from the duplicate light and dark bottles were averaged. The increase in oxygen concentration in the light bottle during incubation is a measure of net production which, because of the concurrent use of oxygen in respiration, is somewhat less than the total or gross production. The loss of oxygen in the dark bottles is used as an estimate of respiration. Thus:

$$\underline{\text{Net Photosynthesis}} = \text{light bottle}_{DO} - \text{initial}_{DO}$$

$$\underline{\text{Respiration}} = \text{initial}_{DO} - \text{dark bottle}_{DO}$$

$$\underline{\text{Gross Photosynthesis}} = \text{light bottle}_{DO} - \text{dark bottle}_{DO}$$

Carbon assimilation was calculated according to the following:

$$\text{mg Carbon fixed}/m^3 = \text{mg oxygen released/liter} \times 12/32 \times 1{,}000$$

$$\text{mg Carbon fixed}/m^3/\text{day} = \text{mgC}/m^3 \times \frac{\text{daily gm cal}}{\text{gm cal during incubation}}$$

TABLE 12

PRIMARY PRODUCTION SAMPLING STATIONS
August 1973

Station Descripiton	River Mile
American Falls Reservoir Near Little Hole	724.8
American Falls Reservoir Near Seagull Bay	718.5
American Falls Reservoir at Dam	714.4
Minidoka Reservoir at Power Station Near Dam	675.3
Milner Pool at Dam	640.0
Brownlee Reservoir at Railroad Bridge	328.3
Brownlee Reservoir near Morgan Creek	318.0
Brownlee Reservoir at Brownlee Creek Cove	288.1

TABLE 13

INCUBATION PERIODS
LIGHT ENERGY RECEIVED AND DEPTH OF EUPHOTIC ZONE
SNAKE RIVER IMPOUNDMENTS - AUGUST 1973

Station Description	Date	Light Energy gm cal/cm^2/day	Incubation Period	Light Energy for Incubation	Depth of Euphotic Zone in Meters
American Falls Reservoir near Little Hole	8/24/73	463	1100-1530	234	.30
American Falls Reservoir near Seagull Bay	8/28/73	561	1000-1345	277	.67
American Falls Reservoir at Dam	8/27/73	549	0945-1345	285	.91
Minidoka Reservoir at Power Station near Dam	8/17/73	486	0900-1400	281	3.7
Milner Pool at Dam	8/16/73	608	1100-1700	431	2.1
Brownlee Reservoir at Railroad Bridge	8/17/73	590	1030-1430	299	1.2
Brownlee Reservoir at Brownlee Creek Cove	8/20/73	619	1115-1515	305	6.1
Brownlee Reservoir near Morgan Creek	8/18/73	700	1000-1400	327	3.7

For a vertical column of water one meter square:

$$mgC/m^2/day = mgC/m^3/day \times \text{euphotic zone depth (m)}.$$

Commonly, primary production is expressed as the amount of carbon incorporated into algal cells in a volume of water per unit time ($mgC/m^3/day$). Primary production can also be expressed as the quantity of carbon fixed by algae for an entire water column ($mgC/m^2/day$). This expression provides for the comparison of primary production of different bodies of water on an areal basis.

In order to compare primary production from different locations and different days, primary production estimates are presented [Table 14] corrected for light variation. This was accomplished by multiplying the observed primary productivity by the following factor:

$$\frac{\text{maximum intensity measured during survey}}{\text{intensity on sample day}}$$

Net respiration (respiration minus production) indicates the DO depletion caused by algae growing in the euphotic zone. Depletion of DO [Table 15] from this source varied considerably (0 to 100 percent) but was significant. In the hypolimnion, the algae exert additional demand for oxygen when they die, settle to the bottom, and decompose.

Primary production on an areal basis was highest in Minidoka (5,159 $mgC/m^2/day$), and Milner was the third highest (3,046 $mgC/m^2/day$) behind Minidoka and a Brownlee station. Primary production on an areal basis for Brownlee Reservoir decreased from 3,830 $mgC/m^2/day$ at mile 328.3, to 1,742 $mgC/m^2/day$ at mile 318.0 and 1,480 $mgC/m^2/day$ at mile 288.1. Turbidity affected primary production in American Falls Reservoir by reducing the euphotic zone depth. Near Little Hole [Figure 5] the euphotic zone

TABLE 14

PRIMARY PRODUCTION

AUGUST 1973

Location	River Mile	Depth (Meters)	Net	Resp	Gross	Measured mgC/m³/day	Measured mgC/m²/day	Corrected mgC/m³/day	Corrected mgC/m²/day
American Falls Reservoir Near Little Hole	724.8	0	4.4	0	4.4	3,265	1,595	479	2,412	724
		0.30	0.2	-.2	0	0				
American Falls Reservoir near Seagull Bay	718.5	0	0.4	0.4	0.8	608	320	209	399	259
		0.67	-0.05	0.1	0.05	38				
American Falls Reservoir at Dam	714.4	0	0.8	0.4	1.2	867	586	526	747	670
		0.91	0.3	0.1	0.4	289				
Minidoka Reservoir at Power Station near Dam	675.3	0	1.9	0	1.9	1,231	994	3,582	1,432	5,159
		1.8	0.6	0.4	2.0	1,297				
		3.7	-.3	0.5	0.2	130				
Milner Pool at Dam	640.0	0	5.6	-0.8	4.8	2,539	1,260	2,645	1,450	3,046
		1.2	0.7	1.1	1.8	952				
		2.1	-.8	1.2	0.4	212				
Brownlee Reservoir at RR Bridge	328.3	0	4.6	1.8	6.4	4,736	2,690	3,228	3,191	3,830
		1.2	-.6	1.4	0.8	592				
Brownlee Reservoir near Morgan Creek	318.0	0	-.1	1.2	1.1	882	484	1,742	484	1,742
		1.8	-.1	0.7	0.6	482				
		3.7	-1.0	1.2	0.2	161				
Brownlee Reservoir at Brownlee Creek Cove	288.1	0	0.2	0.2	0.4	304	217	1,309	246	1,480
		3.0	-.1	0.4	0.3	280				
		6.1	-.5	-0.1	-0.6	0				

TABLE 15

OXYGEN DEPLETION BY ALGAL RESPIRATION
Snake River Basin Study

Station	River Mile	Net-ΔmgO_2/day	Percent Depletion
American Falls Reservoir near Little Hole	724.8	0	0
American Falls Reservoir near Seagull Bay	718.5	1.2	17
American Falls Reservoir at the Dam	714.4	0.4	6
Minidoka Reservoir at Power Station near Dam	675.3	0.3	4
Milner Pool at Dam	640.0	0.5	5
Brownlee Reservoir at the Railroad Bridge	328.3	5.0	52
Brownlee Reservoir near Morgan Creek	318.0	5.6	110
Brownlee Reservoir at Brownlee Creek Cove	288.1	1.5	25

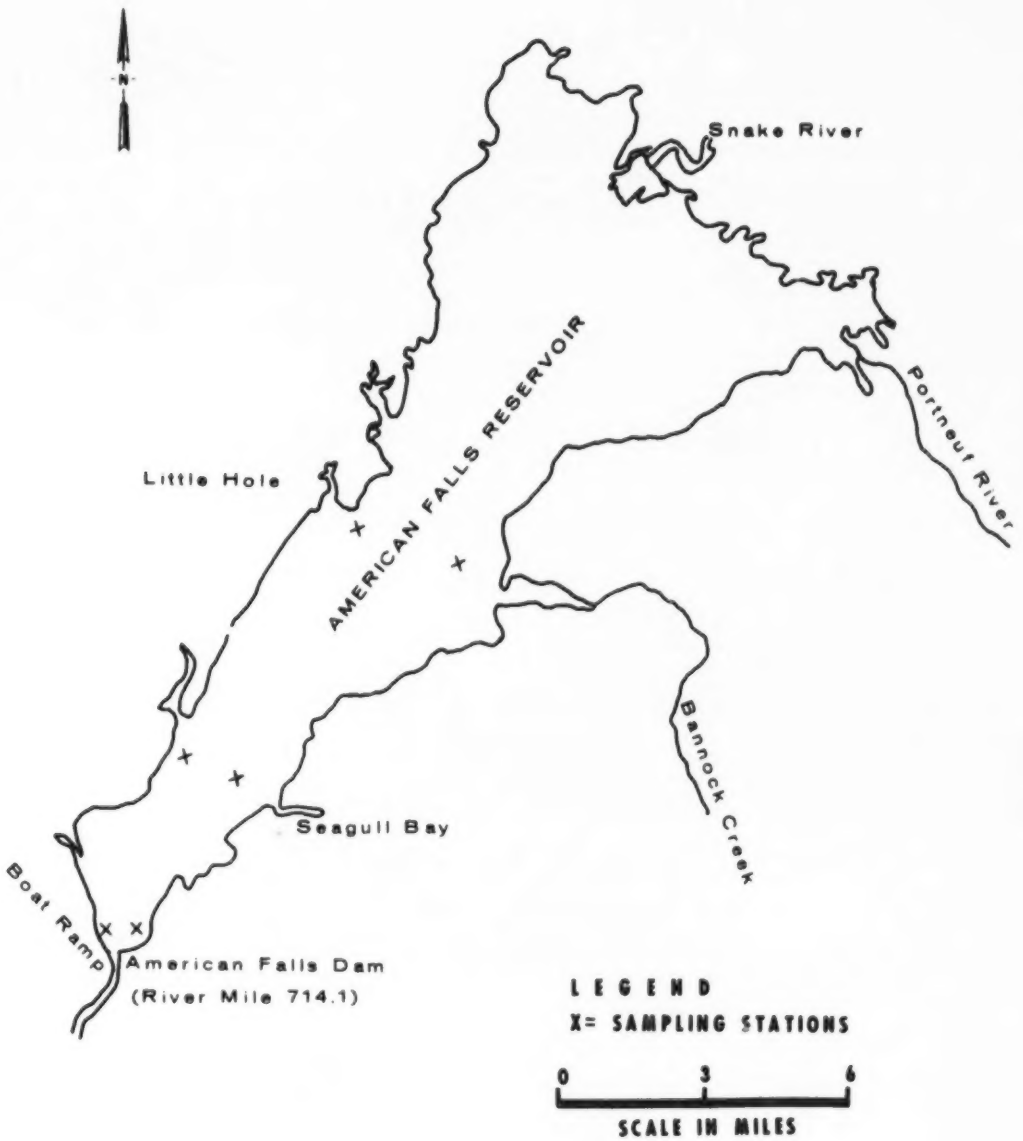

Figure 5. Sampling Stations- American Falls Reservoir, Idaho

August 1973

depth was only 0.3 m (1.0 ft). At Seagull Bay, the euphotic zone increased to 0.66 m (2.1 ft), and at the dam it was 0.9 m (3.0 ft) deep. On a volume basis, American Falls produced from 320 to 1,595 $mgC/m^3/day$ and compared well with the other reservoirs (217 to 2,690 $mgC/m^3/day$). But on an areal basis, American Falls was the least productive (259 to 724 $mgC/m^2/day$) of all reservoirs because of the limited depth of the euphotic zone.

Algal Populations

Algal populations [Table 10] were similar in that Aphanizomenon accounted for from 61 to 98 percent of the algae in each sample. American Falls Reservoir had the lowest numbers of algae. The turbidity of the water may have limited algal number, and strong winds caused algae to mat the shoreline and may have reduced algal densities. Aerial photography also showed algal distribution was not uniform. Corresponding to lower numbers of algae was the fact that primary production was also lower for American Falls than in the other reservoirs tested.

Minidoka Reservoir had the highest numbers of algae and the highest primary production. It receives a heavy nutrient load from American Falls Reservoir and was much less turbid. Milner Reservoir was similar in appearance to Minidoka, but lower numbers of algae were found.

An intense algal bloom existed in all the reservoirs. Brownlee Reservoir is much deeper and longer than the other reservoirs, and the water became much clearer near the dam. The algal population also changed markedly. At Farewell Bend, the phytoplankton community was complex [16 kinds, Table 10] and the water was yellow-green and murky. Downstream about 10 km at RM 328.3, the water appeared about the same (euphotic

zone depth 1.2 m, 4.0 ft) but only 11 kinds of algae were found. Another 16 km downstream at RM 318.0, only Aphanizomenon and centric diatoms were found; the water looked green and was much clearer (euphotic depth 3.7 m, 12.0 ft). At two stations near the dam (RM 288.1 and 285.1) the reservoir water was clearest (euphotic zone depth 6.1 m, 20.0 ft) and 6 and 4 kinds of algae, respectively, were found.

Dissolved Oxygen

Dissolved oxygen measurements [Table 16] were made on each reservoir. None of the samples were obtained from the bottom 6.1 m (20 ft) or bottom 20 percent of the reservoir, as excluded by state standards. The Idaho State DO Standard of 6.0 mg/l or 90 percent saturation applies to all samples in the Table. The DO for 21 of the 26 samples was either less than 6.0 mg/l or 90 percent saturation and in violation of state standards. These samples were all collected between 0845 and 1855 hours. Measurements of 24-hour DO changes were made with Hydro-Lab monitoring equipment utilizing a DO probe at stations in American Falls Reservoir. At 7.6 m (25 ft), the DO decreased to 2.0 mg/l and at the surface the DO decreased to 6.0 mg/l. The DO decreased at night and increased in the daytime, reflecting algal respiration and production. Application of BPCTCA will reduce BOD loading but will have little effect on nutrient loads and corresponding algal caused DO violations.

Field Measurements

Field measurements [Table 16] and observations showed that the reservoirs act as settling basins. Near the dams, suspended solids decreased and euphotic zone depths [Table 14] increased. Also, nutrient

TABLE 16

FIELD MEASUREMENTS

SNAKE RIVER BASIN STUDY

AUGUST 1973

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Station Description	River Mile	Date (Aug)	Time	Depth (Meters)	Water Temp(°C)	DO (mg/l)	Percent Saturation	pH	Chlorophyll a (µg/l)	Sus.Solids (mg/l)	Alkalinity (mg/l $CaCO_3$)
American Falls Reservoir near Little Hol	724.8	23	1820	0	20.0	6.9	75	8.9	9.16	194	
		24	0950	0	17.5	7.4	77	8.4			170
			1000	0.30	17.5	7.2	75	8.4			155
American Falls Reservoir near Bannock Creek	724.8	23	1850	0	20.0	6.9	75	8.5	11.6	530	
American Falls Reservoir near Low Line Canal	718.5	23	1805	0	20.5	7.5	82	8.6	2.64	143	
American Falls Reservoir near Seagull Bay	718.5	23	1745	0	21.5	7.6	85	8.4	3.71	73	
		28	0935	0	17.5	7.2	75	8.4			151
			0950	0.67	18.0	7.1	75	8.4			149
American Falls Reservoir near Boat Ramp at Dam	714.4	23	1855	0	20.5	7.0	77	8.7	2.09	52	
		27	0930	0	18.5	6.8	72	-8.4			152
			0935	0.91	18.5	7.0	74	-8.4			144
American Falls Reservoir in middle near Dam	714.4	23	1845	0	20.5	7.2	79	8.7	6.68	36	
Minidoka Reservoir near Dam	675.3	17	0845	0	21.0	7.7	86	8.6			131
				1.8	21.0	7.8	87	7.0			100
				3.7	20.5	8.0	88	8.8			132
Milner Reservoir near Dam	640.0	16	1000	0	22.0	9.4	107	8.4			137
				1.7	22.0	9.9	112	8.5			137
				2.1	21.8	9.8	110	8.5			135
Brownlee Reservoir at RR Bridge	328.3	17	0920	0	22.5	10.0	114	8.7			149
			1000	1.2	22.0	9.4	107	8.5			134
Brownlee Reservoir near Morgan Creek	318.0	18	0940	0	22.5	5.2	59	8.5			139
			0955	1.8	22.5	5.1	58	8.5			139
			1005	3.7	23.0	5.1	59	8.5			138
Brownlee Reservoir at Brownlee Creek Cove	288.1	20	1040	0	23.0	5.8	67	8.5			127
			1050	3.0	23.0	6.2	71	8.4			126
			1105	6.1	23.5	6.0	70	8.5			127

concentrations are decreased by the algae during the summer. Thus, all the reservoirs acted as biological treatment systems, but they are grossly overloaded. This is evidenced by the fact that most of the nutrient load for Milner and Minidoka Reservoirs comes from American Falls Reservoir.

American Falls Reservoir was undergoing a severe drawdown that may have affected turbidity, suspended solids, and, indirectly, algal densities, chlorophyll a concentrations, and primary production. Normal active storage is 2.1 billion m^3 (1.7 million acre-ft) but during August 1973 the water steadily dropped from 493.4 million m^3 (0.4 million acre-ft) to 246.7 million m^3 (0.2 million acre-ft). The upper half of the reservoir looked more like a river than a reservoir.

The laboratory, monitoring, and field investigations provided data concerning algal problems in reservoirs of the Snake River Basin. Nutrient levels fluctuated extensively with changing seasons, wastes, and stream conditions [Tables 2, 8 and 9]. Nutrient levels appeared to decrease in the reservoirs in the summer, but this is misleading because the algal bloom ties up much of the nutrient supply. Algal growth potential tests were similar in that meat packing waste, treated sewage, and phosphate reduction waste all stimulated algal blooms [Figures 2 and 3]. The algal growth limiting nutrient changed from phosphorus in March to nitrogen in August for three of the reservoirs tested [Table 4]. Nutrient removal tests were successful in removing more than 84 percent of the inorganic N and total P from each effluent tested, but in order to eliminate algal blooms all major sources of nutrients must be controlled.

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APPENDIX A

NUTRIENT POINT SOURCE DATA

TABLE A-1

TOTAL PHOSPHORUS POINT SOURCE CONTRIBUTIONS

October 1971

Discharger	River Mile	Average cfs	mg/l	lbs/day
Municipal				
Idaho Falls STP	797.2	8.2	6.40	286
Blackfood STP	762.0	1.1	9.30	52
Pocatello STP	736.0/13.2	8.05	8.90	383
Rupert STP	665.1	2.3	12.50	158
Heyburn STP	653.4	0.15	10.40	11
Burley STP	652.9	1.2	4.30	28
Industrial				
Golden Valley Packers	812.6	0.46	6.30	16
Idaho Potato Foods	804.0	1.1	5.77	30
Western Farmers	799.6	1.6	10.00	60
U & I Outfall (IF Storm Sewer)	799.4	8.2	0.27	12
Rogers Bros. 001	799.3	1.7	4.80	43
Rogers Bros. 002	799.2/0.1	0.62	1.58	5
Idaho Potato Starch	797.9	0.77	33.20	149
R.T. French Outfall (Shelley Storm Sewer)	787.6	1.55	3.04	29
Idaho Potato Starch	764.1	0.46	18.90	42
American Potato Co. Eff	763.4	3.1	6.21	105
Papoose Springs Trout Farm	736.0/11.6	74.3	0.11	36
J.R. Simplot 001 - Poc	736.0/13.6	2.3	32.40	355
J.R. Simplot 002 - Poc	736.0/13.7	0.46	29.20	50
FMC	736.0/13.7	4.3	4.70	108
J.R. Simplot 001 - Bur	653.8	7.7	10.70	442
J.R. Simplot 002 - Bur	653.7	3.6	0.85	16
Ore-Ida 004	648.9	0.93	0.83	5
Ore-Ida 003	648.7	0.93	0.02	1
Ore-Ida 002	648.7	1.9	1.40	14
Ore-Ida 001	648.4	6.0	17.10	560
A&P	648.4	1.2	0.52	3
Amalgamated Sugar Eff	646.9/8.7	13.8	0.55	40

TABLE A-2

SUMMARY TOTAL PHOSPHOROUS - PERCENT CONTRIBUTIONS

October 1971

Source	Pounds/Day	Percent Contribution
Above Idaho Falls to American Falls Dam		
Industrial *	1020	34
Municipal	730	25
Tributaries **	340	11
Snake River above IF Power House	880	30
	2970	100%
American Falls Dam to Milner Dam		
Industrial	1070	21
Municipal	230	4
Snake River below American Falls	3960	75
	5260	100%
Above Idaho Falls to Milner Dam		
Industrial *	2100	49
Municipal	960	22
Tributaries **	340	8
Snake River above IF Power House	880	21
	4280	100%

*Not including Golden Valley Packers
**Blackfoot River, Aberdeen Drain

TABLE A-3

MARCH 1972 SURVEY DATA

Location	River Mile	Flow (cfs)	NO_3-N mg/l	NO_3-N lb/day	Kjeldahl-N mg/l	Kjeldahl-N lb/day	Total-P mg/l	Total-P lb/day	Ortho-P mg/l	Ortho-P lb/day
Snake River above IF Power Plant	804.7	9,550	0.22	11,300	0.9	46,300	0.04	2,060	0.01	510
Snake River at Tilden Bridge	751.0	10,000	0.26	14,000	0.5	26,900	0.10	5,390	0.02	1,080
Snake River below American Falls Dam	714.0	4,500	0.39	9,450	0.6	14,500	0.11	2,670	0.04	970
Snake River below Minidoka Dam	674.9	3,980	0.35	7,500	0.7	15,000	0.11	2,360	0.05	1,070
Snake River below Milner Dam	639.7	5,520	0.47	14,000	0.80	23,800	0.15	4,460	0.07	2,080

TABLE A-4

TOTAL PHOSPHOROUS POINT SOURCE CONTRIBUTIONS

August 1972

Source	River Mile	Flow Avg cfs	mg/l	lbs/day	Percent Contributions
Irrigation & Tributaries					
South Fork Teton	837.4/11.1/8.5	580	0.06	190	*
North Fork Teton	837.4/20.4/11.8	500	0.04	110	*
Henry's Fork	837.4/34.9	2170	0.03	350	*
Spring Creek W. of Menan	820.1	89	0.02	10	< 0.5
Dry Bed Canal W. of Lewisville	815.7	1060	0.03	170	4
Southparks-Lewisville Canal	815.0/1.2	239	0.04	51	1.0
Market Lake Canal	813.2	65	0.02	7	< 0.5
North Fork Willow Creek	801.4/.1	30	0.08	13	0.5
South Fork Willow Creek	800.7/.1	9.5	0.05	3	< 0.5
Crow Creek	799.0/.2	11.4	0.08	5	< 0.5
Waste Ditch	786.1	150	0.05	40	1.0
Blackfoot River near Mouth	751.2	198	0.12	130	3.0
Diggie Creek	747.8/.75	100	0.02	43	1.0
Jeff Cabin Creek	744.4/1.6	50	0.09	24	0.5
McTucker Springs	739.7	26	0.33	46	1.0
Spring - 3 1/2 miles SE of Springfield	738.6/.9	5	0.08	2	< 0.5
Spring 12C	738.4/.3	36	0.26	50	1.0
Danielson Creek	738.5/.1	80	0.10	43	1.0
Drain near Sterling	738.3/.1	27	0.11	16	0.5
Spring Creek near Blackfoot	735.5/5.4	459	0.09	220	5.5
Clear Creek	738.4/5.05	120	0.03	19	0.5
Gibson Drain	738.4/4.25/1.3	20	0.07	7	< 0.5
Ross Fork Creek	738.4/.01/9.8	37	0.20	40	1.0
Portneuf River at Syphon Road	736/11.7	180	0.81	786	*
Portneuf River at Rowlands	736/13.0	180	0.68	660	*
Spring at Rowlands Dairy	736/13.3	30	0.36	58	1.5
Portneuf River above Zwiegerts	736/17	180	0.14	135	*
Bannock Creek	727/2.5	41	0.15	33	1.0
Aberdeen Drain	726.1/3.6	30	0.09	14	0.5
Rock Creek	704.1/0.9	15	0.08	6	< 0.5

TABLE A-4 (Cont)

TOTAL PHOSPHOROUS POINT SOURCE CONTRIBUTIONS

August 1972

Source	River Mile	Flow Avg cfs	mg/l	lbs/day	Percent Contributions
Crystal Waste		16	0.08	7	< 0.5
Artesidan Springs		3	0.10	2	< 0.5
Colburn Waste		2	0.08	1	< 0.5
Tartar Waste		12	0.08	5	< 0.5
Schlitz Waste		4	0.08	2	< 0.5
Cedar Waste		22	0.08	9	< 0.5
Triple Creek		20	0.05	5	< 0.5
Fort Hall Michaud Canal		77	0.03	12	< 0.5
Unmeasured Inflow		1300	0.05	350	8.5
Into Snake River Above American Falls Res.					
Parsons Ditch		48	0.08	21	0.5
Weary Rick Ditch		55	0.08	24	0.5
Wattson Ditch		102	0.08	44	1.0
Trego Ditch		56	0.08	24	0.5
					44%

*Not included in point source total phosphorous percent contributions.

NOTE: Inconsistencies may be due to rounding.

TABLE A-4 (Cont)

TOTAL PHOSPHOROUS POINT SOURCE CONTRIBUTIONS

August 1972

Source	River Mile	Flow Avg cfs	mg/l	lbs/day	Percent Contributions
Fall Creek	699.75/.06	21	0.02	2	< 0.5
Raft River	692.0/1.4	3	0.08	1	< 0.5
D3	668.05/0.6	4.7	0.11	3	< 0.5
D4	664.8/0.95	4.3	0.16	3	< 0.5
D5	663.7/0.3	16	0.09	8	< 0.5
D5C	662.55	0.5	0.16	< 1	< 0.5
Marsh Creek	660.42	25	0.21	28	0.5
Spring Creek Drain	659.3	12	0.18	12	< 0.5
Rasmussen Drain	658.82/1.3	1.8	0.18	2	< 0.5
Goose (Snipe) Creek	653.99	19.4	0.15	16	0.5
D16	653.7	19	0.16	16	0.5
D7	653.4/0.3	.83	0.14	< 1	< 0.5
B-Canal	652.7	26	0.08	11	< 0.5
D12A	652.35/0.5	17	0.13	12	< 0.5
D13	652.0/0.5	1.5	0.14	1	< 0.5
Morgan Gulch Drain	649.61/0.9	3	0.3	5	< 0.5
D17	648.30/3.5	10.6	0.13	7	< 0.5
Main Drain	646.9/1.8	18	0.22	21	0.5
J Wasteway	645.30/1.4	23	0.10	12	< 0.5
Estimated Loading-Unsampled Sources Into American Falls Reservoir					
Big Jimmy Creek		26	0.05	7	< 0.5
Ford Creek		6	0.05	2	< 0.5
Kinney Creek		28	0.05	8	< 0.5
Wide Creek		47	0.05	13	< 0.5
Pyle Springs		7	0.10	4	< 0.5
Hull Springs		8	0.10	4	< 0.5
Tanner Springs		1	0.10	< 1	< 0.5
Crystal Ditch		2	0.08	1	< 0.5

TABLE A-4 (Cont)

TOTAL PHOSPHOROUS POINT SOURCE CONTRIBUTIONS

August 1972

Source	River Mile	Flow Avg cfs	mg/l	lbs/day	Percent Contributions
Municipal					
Idaho Falls Storm Sewer (U&I Outfall)	799.2	4.7	0.94	24	0.5
Idaho Falls STP	797.2	14.7	7.7	610	15.0
Shelley Outfall (R.T. French)	787.6	1.1	0.08	1	< 0.5
Shelley STP	787.0	0.26	3.5	5	< 0.5
Blackfoot STP	762.0	1.6	5.9	51	1.5
Pocatello STP	736.0/13.2	7.0	9.3	350	8.5
American Falls STP	713.5	1.0	6.7	36	1.0
Rupert STP	665 1	3.6	5.2	101	2.5
Heyburn STP	653.4	0.28	7.2	11	< 0.5
Burley STP	652.9	1.6	4.9	42	1.0
					30%
Industrial					
Golden Valley Packers	816.2	0.99	4.5	24	0.5
J.R. Simplot 001 - Poc	736.0/13.6	1.75	14.3	135	3.5
J.R. Simplot 002 - Poc	736.0/13.7	0.57	43.6	134	3.5
FMC	736.0/13.7	5.15	6.8	189	4.5
Union Poc. R.R.	736.0/16.8	0.36	1.7	3	< 0.5
Rueger Springs - Hatchery Eff.	712.3	19	0.11	11	< 0.5
J.R. Simplot 001 - Bur	653.8	7.5	4.7	190	4.5
Ore-Ida Process	648.7	6.6	10.5	373	9.0
					26%
Summary					
Irrigation & Tributaries				1760	44
Municipal				1230	30
Industrial				1060	26
				4050	100%

TABLE A-5

SUMMARY TOTAL PHOSPHOROUS - PERCENT CONTRIBUTIONS

August 1972

Source	Pounds/Day	Percent Contribution
Lorenzo to American Falls Dam		
Industrial	490	10
Municipal	1040	22
Irrigation and Tributaries	1590	33
NF & SF Teton, Henry's Fork	650	14
Snake River at Lorenzo	980	21
	4750	100%
American Falls Dam to Milner Dam		
Industrial	570	11
Municipal	190	4
Irrigation and Tributaries	170	3
Snake River below American Falls	4260	82
	5190	100%
Lorenzo to Milner Dam		
Industrial	1060	19
Municipal	1230	22
Irrigation and Tributaries	1760	31
NF & SF Teton, Henry's Fork	650	11
Snake River at Lorenzo	980	17
	5680	100%

APPENDIX B

IDAHO STATE WATER QUALITY STANDARDS

EXTRACTS FROM "WATER QUALITY STANDARDS AND WASTEWATER TREATMENT REQUIREMENTS," IDAHO DEPARTMENT OF ENVIRONMENTAL AND COMMUNITY SERVICES (Pages 8-11)

"Natural tributaries to the stream reaches are classified as primary recreational waters, Class A_2, unless otherwise specified. Waterways defined as a point source in Section 502(14), Public Law 92-500, are a means of conveyance for waters with no use classification. Canals and other man-made waterways excluded as a point source are protected for agricultural uses and aesthetic qualities and may be protected for other uses when specified.

In the instance where a flowing stream is classified and subsequently becomes an impoundment, that impoundment shall carry the same classification as the flowing stream. The criteria established for the various use-classifications may be modified by the Administrator for limited periods when receiving waters fall below their assigned water quality standards due to natural causes or if, in the opinion of the Administrator, the protection of the overall interest and welfare of the public requires such a modification.

VII. GENERAL WATER QUALITY STANDARDS FOR WATERS OF THE STATE

The following general water quality standards will apply to waters of the State, both surface and underground, in addition to the water quality standards set forth for specifically classified waters. Waters of the State shall not contain:

A. Toxic chemicals of other than natural origin in concentrations found to be of public health significance or to adversely affect the use for which the waters have been classified.*

B. Deleterious substances of other than natural origin in concentrations that cause tainting of edible species of fish or tastes and odors to be imparted to drinking water supplies.

C. Radioactive materials or radioactivity other than of natural origin which

1. Exceed 1/3 of the values listed in Column 2, Table II, Appendix A, Idaho Radiation Control Regulations as adopted by the Board on May 9, 1973.

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* Guides such as the Water Quality Criteria published by the State of California Water Quality Control Board (Second Edition, 1963) and more recent research papers will be used in evaluating the tolerances of the various toxic chemicals for the use indicated.

2. Exceed the concentrations specified in the 1962 U.S. Public Health Service Drinking Water Standards for waters used for domestic supplies.

3. Have a demonstrable effect on aquatic life.

The concentration of radioactive materials in these waters shall be less than those required to meet the Radiation Protection Guides for maximum exposure of critical human organs recommended by the former Federal Radiation Council in the case of foodstuffs harvested from these waters for human consumption.

D. Floating or submerged matter not attributable to natural causes.

E. Excess nutrients of other than natural origin that cause visible slime growths or other nuisance aquatic growths.

F. Visible concentrations of oil, sludge deposits, scum, foam or other material that may adversely affect the use indicated.

G. Objectionable turbidity which can be traced to a man-made source.

VIII. SPECIFIC WATER QUALITY STANDARDS

No wastewaters shall be discharged and/or no activity shall be conducted in waters of the State which either alone or in combination with other wastewaters or activities will cause in waters of any specified reach, lake or impoundment, or in general surface waters of the State

A. The organism concentrations of the coliform group

1. The waters of lakes and impounds (A_1), except the following, which are classified as A_2 waters:

American Falls	R.M. 738.0 to R.M. 714.0
Lake Walcott	
Milner Lake	R.M. 675.0 to R.M. 640.0
Murtaugh Lake	R.M. 690.0 to R.M. 675.0
Crane Falls Reservoir	
C. J. Strike Reservoir	R.M. 514.0 to R.M. 492.0
Lake Lowell	
Brownlee Reservoir	R.M. 338.0 to R.M. 285.0
Oxbow Reservoir	R.M. 285.0 to R.M. 273.0
Hells Canyon Reservoir	R.M. 273.0 to R.M. 247.0

a. Total coliform concentrations where associated with a fecal source(s) to exceed a geometric mean of 50/100 ml., nor shall more than 20 percent of total samples during any 30-day period exceed 200/100 ml. (as determined by multiple-tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period).

b. Fecal coliform concentrations to exceed a geometric mean of 10/100 ml., nor shall more than 10 percent of total samples during any 30-day period exceed 20/100 ml.; or greater than 50/100 ml. for any single sample.

Coliform criteria for shoreline waters shall conform with that of Class A_2 waters. Shoreline water waters shall be defined as the 100 feet of water surface as measured from the shoreline.

2. In waters protected for primary contact recreation (A_2)

a. Total coliform concentrations where associated with a fecal source(s) to exceed a geometric mean of 240/100 ml., nor shall more than 20 percent of total samples during any 30-day period exceed 1000/100 ml. (as determined by multiple-tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period).

b. Fecal coliform concentrations to exceed a geometric mean of 50/100 ml., nor shall more than 10 percent of total samples during any 30-day period exceed 200/100 ml.; or greater than 500/100 ml. for any single sample.

3. In waters protected for secondary contact recreation (B)

a. Total coliform concentrations where associated with a fecal source(s) to exceed a geometric mean of 1000/100 ml., nor shall more than 20 percent of total samples during any 30-day period exceed 2400/100 ml. (as determined by multiple-tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period).

b. Fecal coliform concentrations to exceed a geometric mean of 200/100 ml., nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml.; or greater than 800/100 ml. for any single sample.

B. Dissolved Oxygen

The DO concentration to be less than 6 mg/l or 90 percent of saturation, whichever is greater.

1. The DO standard shall apply to all flowing waterways.

2. The DO standard shall apply to the waters of all natural lakes and reservoirs except as excluded below:

   a. In depths of water less than 100 feet in natural lakes or reservoirs, the bottom 20 percent of water depth shall be excluded from application of the DO standard. In water depths greater than 100 feet, the bottom 20 feet of water depth shall be excluded for application of the DO standard.

   b. Waters below a thermocline in stratified lakes or impoundments shall be excluded from application of the DO standard.

   c. No wastewaters shall be discharged and/or no activity shall be conducted in waters excluded by a. and b. above, which either alone or in combination with other wastewaters or activities will cause the DO concentration in these waters to be less than 4 mg/l.

3. Notwithstanding exclusion of a. and b. above, the DO standard shall always apply to the top two feet of any lake or reservoir.

C. Hydrogen Ion Concentration (pH)

The pH values to be outside the range of 6.5 to 9.0. The induced variations shall not be more than 0.5 pH units.

D. Temperature

1. Any measurable increase when water temperatures are 66°F or above, or more than 2°F increase other than from natural causes when water temperatures are 64°F or less (unless otherwise specified).

2. Any increase exceeding 0.5°F due to any single source, or 2°F due to all sources combined.

For purposes of determining compliance, a "measurable increase" means no more than 0.5°F rise in temperature of the receiving

water as measured immediately outside of an established mixing zone. Where mixing zone boundaries have not been defined cognizance will be given to the opportunity for admixture of wastewater with the receiving water.

3. Any measurable increase when water temperatures are 68°F or above, or more than 2°F increase other than from natural causes when the water temperatures are 66°F or less in the following waters:

   a. The main stem of the Snake River from the Oregon-Idaho border (R.M. 407) to the interstate line at Lewiston, Idaho (R.M. 139).

   b. The Spokane River from Coeur d'Alene Lake outlet to the Idaho-Washington border.

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